Hurricane and Severe Storm Sentinel (HS3)
Airborne Sciences and the background to HS3

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Questions

- Why does NASA do airborne science?
- What sort of platforms do we use?
- Why do we investigate hurricanes?
- What are our science questions?
- What do we need to answer our questions?
Why does NASA do airborne science?

- Satellites can’t do it all
  - Process studies for focused science questions
- Some science requires 24-hour measurements
  - Monitoring and Applications
- Satellites instruments can’t be brought back
  - Satellite validation
- How do we take a instrument concept from the lab to space?
  - Space-based instrument test-beds, algorithm development, IIP implementation
What planes does NASA operate?
Reconfigurable flying laboratories
Close to 100 million Americans now live within 50 miles of a coastline, thus exposing them to the potential destruction caused by a landfalling hurricane.

- 2011: Irene (Cat 3 to 1), 56 deaths and an estimated 15.6B in damages
- 2008: Gustav (Cat 2, 26 deaths), Ike (17 deaths, 2 million homes without power)
- 2005: Katrina (~1800 deaths, 100B in damages)
<table>
<thead>
<tr>
<th>Category</th>
<th>Max sustained wind speed</th>
<th>damage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mph</td>
<td>knots</td>
</tr>
<tr>
<td>1</td>
<td>74-95</td>
<td>64-82</td>
</tr>
<tr>
<td>2</td>
<td>96-110</td>
<td>83-95</td>
</tr>
<tr>
<td>3</td>
<td>111-130</td>
<td>96-113</td>
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<tr>
<td>4</td>
<td>131-155</td>
<td>114-135</td>
</tr>
<tr>
<td>5</td>
<td>156+</td>
<td>136+</td>
</tr>
</tbody>
</table>
Hurricanes present many dangers:

- High winds
- Storm surge
- Tornadoes
- Flooding
Hurricane dangers!


Freshwater Flooding 59%

Wind 12%
Surf 11%
Offshore 11%
Tornado 4%
Other 2%
Surge 1%

Source: Edward Rappaport—Chief, Technical Support Branch, Tropical Prediction Center
Aircraft

- Aircraft recon since 1940’s
- NOAA recon since 1956
- Information on hurricane position, intensity and structure
NASA field campaigns have helped develop a better understanding of hurricane properties, including inner core dynamics, rapid intensification and genesis.

- We do field experiments to accomplish:
  - calibration/validation of satellite sensor
  - evaluation of new sensor concepts
  - process studies
What are our questions?

- What impact does the large-scale environment, particularly the Saharan Air Layer (SAL), have on intensity change?
- What is the role of storm internal processes such as deep convective towers?
- What determines whether a storm undergoing transition to an extratropical storm intensifies?
- To what extent are these intensification processes predictable?
What do we need?

- A high altitude platform to observe the entire hurricane
- A long range platform to enable us to sample any target
- A platform with enough duration to provide more than just a “snapshot”.

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Image with NASA Hurricane and Severe Storm Sentinel HS3 logo.
Basics – tropical temperature

The graph illustrates the relationship between altitude (in kilometers) and temperature (in °F). The troposphere is the layer closest to the Earth’s surface, with very cold temperatures, while the stratosphere, located above the troposphere, has very warm temperatures. The tropopause, the boundary between these two layers, is marked by a significant change in temperature.

Key Points:
- Troposphere: Very cold temperatures
- Stratosphere: Very warm temperatures
- Tropopause: Boundary between troposphere and stratosphere

The graph shows a downward trend in temperature as altitude increases, indicating the lowering temperature with altitude in both the troposphere and stratosphere.
Basics – tropical temperature

Hurricanes extend up to 40,000 feet, with some features extending into the stratosphere.
We need a platform that can overfly hurricanes to see the whole structure.

The NASA Global Hawk flies at 65,000 feet.

Airliners fly between 30 and 40,000 feet.

Hurricanes extend up to 40,000 feet, with some features extending into the stratosphere.
Basics – tropical air motion

Bermuda high, note clockwise motion

T (K) Sept. ~4.8kft

0.2 8.5 8.5 0.2

m/s
Basics – tropical air humidity

Relative Humidity (%) Sep. 2.5 kft

Blue shows very dry air

Dry air comes out of the Sahara (Saharan Air Layer or SAL)

Red shows very wet air
Basics – tropical air dust

How does this hot & dry Saharan air affect hurricanes? We need a platform that can fly to the central Atlantic.

SAL air is also very very dusty.
The NASA Global Hawks can sample any hurricane in the Atlantic, Caribbean, or Gulf of Mexico and remain on them for many hours!
What is the NASA Global Hawk UAS?

Where’s the pilot?
GH numbers

Global Hawk

Boeing 737-700

737 wingspan = 112 feet
ER–2 length = 110 feet
GH numbers

737 wingspan = 112 feet
ER-2 length = 110 feet

Global Hawk

<table>
<thead>
<tr>
<th><strong>Range</strong></th>
<th>&gt;11,500 mi</th>
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</thead>
<tbody>
<tr>
<td><strong>Endurance</strong></td>
<td>&gt;30 hours</td>
</tr>
<tr>
<td><strong>Maximum Altitude</strong></td>
<td>65,000 feet</td>
</tr>
<tr>
<td><strong>Gross Weight</strong></td>
<td>26,750 lbs</td>
</tr>
<tr>
<td><strong>Fuel Capacity</strong></td>
<td>15,300 lbs</td>
</tr>
<tr>
<td><strong>True Airspeed</strong></td>
<td>385 mph</td>
</tr>
<tr>
<td><strong>Payload Weight</strong></td>
<td>1500 lbs</td>
</tr>
<tr>
<td><strong>Payload Volume</strong></td>
<td>&gt;100 ft³</td>
</tr>
<tr>
<td><strong>Airfield requirement</strong></td>
<td>8,000 x 150 feet</td>
</tr>
<tr>
<td><strong>Fuel</strong></td>
<td>JP-8</td>
</tr>
<tr>
<td><strong>Autonomous all phases of flight</strong></td>
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Hurricane Earl’s eye as seen from the GH
The GH is a fully autonomous UAS that is controlled by its own software and is continually operated by pilots on the ground using satellite links.

The GH can:
- Fly at high altitude (over hurricanes)
- Fly long range (sampling hurricanes in the distant Atlantic)
- Fly long-duration (orbiting over hurricanes for many hours)
GRIP Accomplishments

• Major cases
  • Multi-day flights of covering the genesis of Karl, Matthew, and non re-genesis of Gaston
  • DC-8 flights for RI of Earl (from Cat1 to Cat4)
  • DC-8 & GH flights of RI of Karl (from Cat1 to Cat3)

• Technical Achievements
  • First GH flight over a hurricane
  • 20 GH eye crossings in one flight over Karl
Summary

- NASA employs aircraft in a variety of roles to support its satellite missions, develop new instrumentation, and to answer science questions.
- The Global Hawk unmanned aircraft system (UAS) is the newest addition to the NASA fleet.
- Questions about how hurricanes form and intensify require a heavy lift, long-endurance, long-range, and high-altitude platform.
- The Hurricane and Severe Storm Sentinel Mission will use two Global Hawks to explore hurricanes in the Atlantic-Caribbean-Gulf region in the years 2012, 2013, and 2014.